

## A SONIFICATION OF KEPLER SPACE TELESCOPE STAR DATA

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### ABSTRACT

A performing artist group interested in including a sonification of star data from NASA's Kepler space telescope in their next album release approached the Georgia Tech Sonification Lab for assistance in the process. The artists had few constraints for the authors other than wanting the end product to be true to the data, and a musically appealing "heavenly" sound. Several sonifications of the data were created using various techniques, each resulting in a different sounding representation of the Kepler data. The details of this process are discussed in this poster. Ultimately, the researchers were able to produce the desired sounds via sound synthesis, and the artists plan to incorporate them into their next album release.

### 1. INTRODUCTION

A representative of a professional group of musicians recently came to the authors for advice on how to properly sonify data obtained from stars. The initial request was for the researchers to produce any kind of musical result with the only constraint being that the sounds must be produced purely from star data. In other words, no artificial constructions or manipulations of sound were to be accepted. Ideally, the sonifications produced were to be utilized in the musicians' next major album release and therefore also required the sounds to be musical in some form. In an effort to create these desired sounds the project extended into the realms of many relevant subfields of sonification including digital signal processing, audio synthesis, and general sound design. Each of these approaches is presented in this poster.

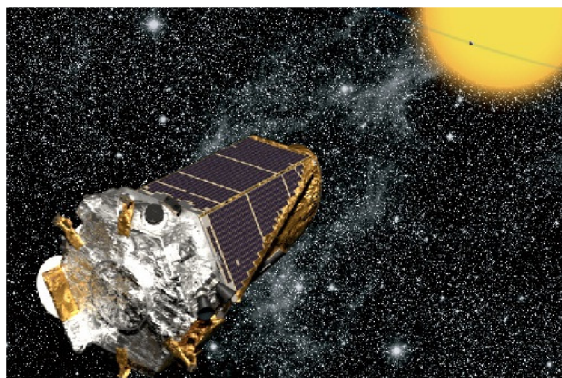


Figure 1: Artist's rendition of the Kepler spacecraft [1]

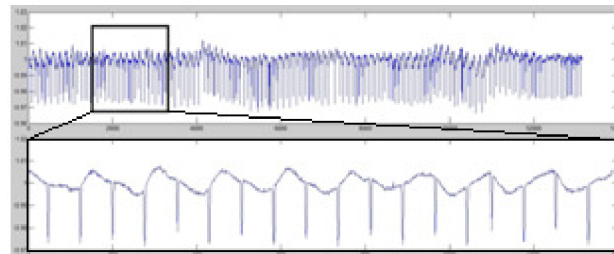


Figure 2: The top graph shows an original waveform as retrieved from planethunters.org, as graphed from within MATLAB. The black inset highlights one particular segment while the lower graph is a magnified image of that signal.

### 2. KEPLER DATA

The data that the authors were given were produced by NASA's Kepler space telescope pictured in Figure 1 and were gathered from the public site planethunters.org [2]. The data contained brightness values for certain stars across long periods of time. This data set was created by the telescope in the search for terrestrial planets within habitable zones of stars [1]. The fluctuations in the brightness values represent when a planet is passing between the Kepler telescope and the star it is focused on, an example of which is displayed in Figure 2.

### 3. SONIFICATION SANDBOX

Initially, the authors were asked to produce a general sonification for a sample set of data. To comply, the Sonification Sandbox [3] was utilized. This software package is available freely to the public, and was designed by researchers from the Georgia Tech Sonification Lab. For this first iteration, the data were simply imported into the software and the data values were mapped to various MIDI pitches. This technique was used as it is a standard first step when sonifying data. The Sonification Sandbox automatically handles mapping the values to certain pitches, which means the user is free to adjust further parameters such as timbre, tempo, frequency range, and others. An issue that arose with this approach involved the limited variability of the data sets. Since most of the stars' brightness values centered around 1 and the standard deviation was frequently on the thousandths scale, the software often had issues assigning frequency values to the clustered data points. To correct this, the data were standardized in a way that occupied a significantly larger range of values and was centered

on zero. An example of this output can be heard by listening to “0-Sandbox.midi.”

#### 4. AUDIFICATION IN MATLAB

The resulting samples from the Sonification Sandbox attempt were well received, however, the sound produced was not what the musicians wanted to use in their project. More specifically, the musicians were looking for timbres comprised of star data, not sequences of sonified musical pitches. In an effort to make the sounds more closely reflect the “heavenly” tones the musicians wanted, the authors tried a different approach. Instead of sonifying by mapping the brightness values to discrete MIDI pitches, the entire dataset was imported into MATLAB and audified (see [4]) via the `soundsc()` function. This simply plays back the data as a waveform while automatically scaling the values to an appropriate range. An example of this raw audification can be heard by listening to “1-MATLAB.wav.” Since sample length was not a concern at this point in the research, sampling frequency was manipulated in order to quickly change pitch. This resulted in a much more applicable tone.

#### 5. ADAPTING THE TONE

After this point, the musicians decided that the type of sound was beginning to approach the desired characteristics and all that needed to be refined was the timbre. The musicians were searching for a very specific kind of tone—one that could be described as heavenly or angelic. To solve this, the authors sifted through the numerous data sets located at [planethunters.org](http://planethunters.org) in order to find a clean signal that would produce the desired timbre. Sinusoidal, periodic, or otherwise regularly patterned data sets were targeted and several were found. The previous procedure with MATLAB was then used to produce a new set of waveforms with star SPH10105467, as seen raw in Figure 3 and cleaned in Figure 4.

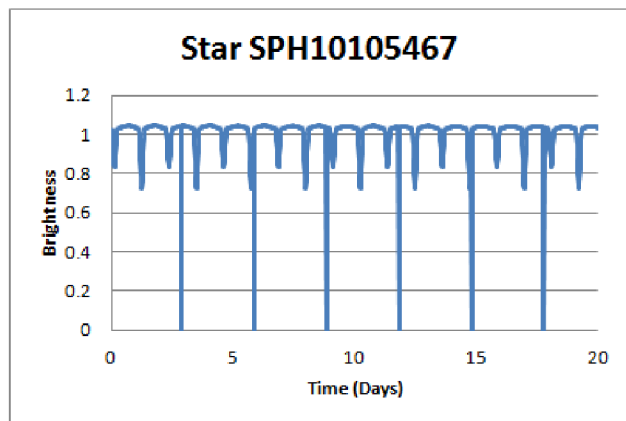


Figure 3: The graph shows the original waveform for star SPH10105467 as retrieved from [planethunters.org](http://planethunters.org). The vertical lines represent zeros (errors) in the data set. This is just one example of an artifact that contributed to noise in the original signal.

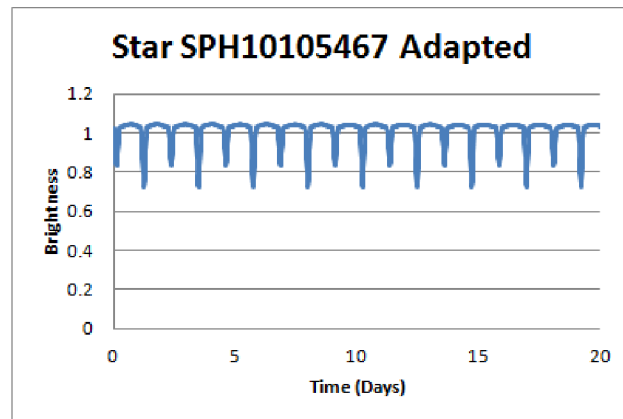


Figure 4: The graph shows the waveform for star SPH10105467 after cleaning the error values from the data set.

Further iterations of sounds were produced via experimentation with several different procedures. Upon initial creation of the waveforms in MATLAB, simple filtering was employed to clean the signals. For one series, as shown in Figure 2, one small segment of a signal was extracted. This small clip was then repeated numerous times, thus resulting in an extended version of this one segment. Simple bandpass filters were then applied in order to remove frequencies outside of the range 150 - 800Hz. This process yielded samples as heard in “2-Filtering.wav.” This tone was much closer to the expected timbre, but it had some unnatural harmonics. The artists still desired a cleaner tone, so the researchers utilized the curve fitting tool in MATLAB in order to further remove some of the noise and artifacts that were evident in the natural data. This process yielded a more aesthetic tone, and it can be heard by listening to “3-CurveFitting.wav.” The musicians greatly preferred the pure tone that this process yielded, and they then requested a set of 24 different musical pitches to compose the melody that will ultimately be used in the album. A short excerpt of this raw melody can be heard by listening to “4-Melody.wav.”

#### 6. PERFECTING THE MELODY

Once the previous waveforms were compiled into a short melody by the musicians, the authors decided to experiment with the sound’s timbre further by applying an amplitude envelope. They found this to be the best route to maintain the clean pitch of the sounds and still make them have the desired timbral characteristics. This was accomplished by using data from another star (SPH10105611, see Figure 4) and applying those data points as an amplitude envelope onto the carrier signal of the composed melody. This method was accomplished by using MATLAB’s `interp1()` function, linear interpolation, to stretch the envelope signal to the length of the melody. After scaling the envelope signal to a range between 0-1, the `times()` function was used to multiply the melody and envelope vectors together, thus applying a musical tremolo effect onto the entire melody. The resulting track was then sent to the musicians, who deemed it to be satisfactory for their final project. The sample melody excerpt from earlier can be heard with the tremolo effect by listening to “5-Envelope.wav.”

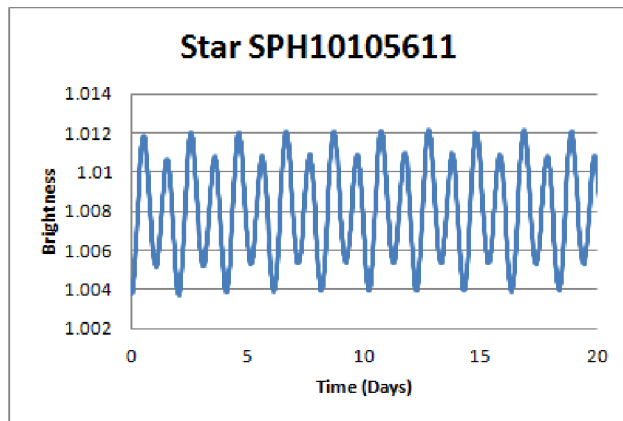


Figure 5: The graph shows the waveform for star SPH10105611, the star used as the amplitude envelope. This star was chosen because of its relatively even periodicity which translates well for a tremolo envelope.

## 7. CONCLUSION

The prior step marked the conclusion of this research endeavor. Currently, the music production is still in press with a release expected to be imminent within the next year. The musicians intend to incorporate a full orchestration atop the given melody, but this final version has yet to be released. Future works related to sonification and audification may yet provide some interesting results, as there are still many other avenues through which one could construct different versions of sonified star data. Regardless, this research yielded an authentic yet aesthetically satisfying auditory construction of star data, while still enabling the musicians to produce their composition with natural sounds made only from one quantitative property of a few stars. This work serves as a guide for future projects in sonification and audification; especially those that have an aesthetic or musical aspect to consider.

## 8. ACKNOWLEDGMENT

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## 9. REFERENCES

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